A NEW LOW COST DIRECT ARCHIVING AND PREPROCESSING SYSTEM FOR KITSAT-3 IMAGE DATA

Taejung Kim*, Impyeong Lee* and Soon Dal Choi**
Research Fellow*, Director**
Satellite Technology Research Center
Korea Advanced Institute of Science and Technology
373-1, Kusung-Dong, Yusung-Gu
Taejon, Korea
email: tjkim@krsc.kaist.ac.kr, iplee@krsc.kaist.ac.kr

Commission I, Working Group I/6

KEY WORDS: Archiving, Hardware, Satellite

ABSTRACT

This paper describe the development of a low cost direct archiving and preprocessing system. The system will be used for a small satellite called KITSAT-3. Among many advantages of the use of small satellites, the feasibility of the development of a simple and low cost ground receiving station is one of the most meaningful as far as the ground segment's concerned. The moderate speed of small satellites makes it possible to replace expensive dedicated hardware by cheap commercial Personal Computers and dedicated software.
In order to develop a low cost direct archiving system, a PC interface card was developed. This card converts incoming stream into parallel words and store them into the hard disk of a PC. For frame synchronization process, a dedicated software was developed. The techniques used for this development are not very complicated, which proves the advantage of the use of small satellites. Although the system developed here has the fundamental limitation of the speed of incoming data stream, the system upgrade should be done also without great difficulties with the fast advancing PC technologies.

1. INTRODUCTION

A earth imaging satellite takes pictures of the earth surface and usually stores a large amount of data onboard recorder. When the communication link between the satellite and the ground receiving station is set up, the image data stored onboard are transmitted to the receiving antenna of the ground station. After reception, appropriate operations should be carried out to restore proper image data and these image data should be stored in real-time.

The development of such ground receiving system is often very complex and difficult as image data are usually very bulky and the data rate from the satellite to the ground station is very high. To handle this high speed data, dedicated hardware such as High Density Tape Recorder (HDTR) and Frame Synchronizer have been developed and used for commercial remote sensing satellites. However, these are very expensive devices and difficult to control.

The idea of the use of small satellites for earth observation is becoming more and more popular as this gives several merits over the use conventional large remote sensing satellites: small satellites are easier and cheaper to manufacture; small satellites are less risky; small satellites can accommodate fast changing user's need better; and etc.. Moreover, the use of small satellites can reduce the size and complexity of the ground receiving station significantly. With this, the development of low cost receiving station is very feasible.

In this paper, the development of a low cost direct archiving and preprocessing system will be described. This system will be used for a small satellite called KITSAT-3. The KITSAT-3 is the third satellite of the KITSAT series manufactured by Satellite Technology Research Center of KAIST, Korea. As this satellite has a down-link speed of 3Mbps, the conventional (expensive) dedicated hardware can be replaced by a commercial computer hardware. The cost effectiveness can be achieved by avoiding the dedicated hardware and, instead, developing dedicated software.

This paper will start with general description of the KITSAT-3 ground receiving system. Section 3 will discuss about the development and the implementation of this system. In particular, implementation will concentrate on the development of a direct archiving recorder and frame synchronization software. Some conclusions are included in section 4.

2. The KITSAT-3 Ground Receiving Station

To begin with, let us describe the KITSAT-3 satellite briefly. A technical detail of this satellite can be found in the references (Kim et al., 1995a; Kim et al., 1995b). The KITSAT-3 is the third series of experimental small satellites by Satellite Technology Research Center at Korea Advanced Institute of Science and Technology (KAIST). This satellite is circulating an sun synchronous low earth orbit with an altitude of 870 km from the ground and producing high quality remote sensing images. This has four scientific instruments-High Energy Particle Telescope, Radiation Effect on Micro-Electronics, Electron Temperature Probe, and Scientific Magnetometer-and an imaging instrument (Kim et al., 1995a).

The imaging instrument has three channels and the resolution of image is 17m. A standard scene (3456 x 3456 pixels) covers 59 x 59 km in the ground. The pointing accuracy of this satellite is relatively low (0.5 degree) cause this satellite is "experimental" but the platform can maintain its stability (0.014 deg/sec drift rate) during the image capture. The size of a scene is about 36 Mbytes. The image data captured by the camera is stored onboard solid-state mass memory devices (~20Gbytes). These image data are transmitted to the ground receiving station in X-band with a transmission rate of 3 Mbps. Table 1 summarizes the system specification of the KITSAT-3 and its camera system.

Table 1. System specification of the KITSAT-3 and its camera system.

KITSAT-3 Weight	100 Kg
Power	100 Watt
Dimension	45x45X60 (cm)
Altitude	870 km
Pointing Accuracy	~0.5 degree
Attitude Stability	0.014 deg/sec
Camera Resolution	17 m
Pixel number per line	3456
Swath	59 Km

Compared with conventional remote sensing satellites, the transmission rate of the KITSAT-3 is relatively low. This makes the development of the ground receiving system easier and less expensive. There is no need to hire a dedicated high speed hardware to handle high speed data. Cheap and conventional moderate speed (in the order of several MHz) devices can be used. In particular, such speed can be handled by a PC hardware. This also gives a great opportunity to simplify the task of the development of the ground receiving station as PCs are normally easier to control.

The following picture is a block diagram of the KITSAT-3 ground receiving station.

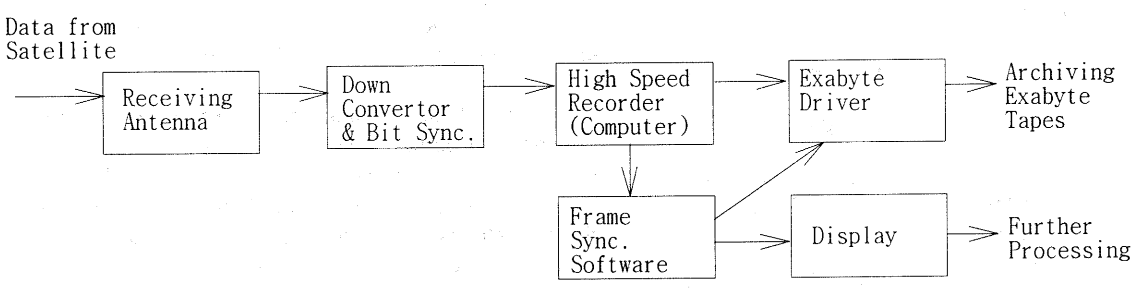

Figure 1. A block diagram of the KITSAT-3 ground receiving station.

KITSAT-3 transmits data (image data + auxiliary data) to the ground receiving station. The selected download frequency for the KITSAT-3 is a X-band frequency. As this signal has already been modulated on the satellite, this undergoes a procedure of down conversion, demodulation, and bit-synchronization. After this procedure, a series of bit stream is created. This input stream should be recorded using an appropriate device. In case of commercial remote sensing satellites with very high frequency, an appropriate device can be a High Density Tape Recorder (HDTR), which is very expensive. However, in case of the KITSAT-3 with the speed of 3 Mbps, it is possible to record the incoming stream using less expensive devices.

A new concept of recorder has been developed. As the speed of incoming bit stream is not very high, a dedicated hardware (such as HDTR) can be replaced by a commercial devices. The core of this new concept is the use of a Personal Computer (PC) as a recorder; the incoming stream is recorded in the hard disk of a PC. The use of PC reduces the cost of the total ground receiving station greatly as a PC is a lot cheaper than, for example, a HDTR. Moreover, the use of PC reduces the complexity of the development of the ground receiving station as a PC is easier to control (than, for example, a HDTR).

A PC can be used as a recorder by using a PC interface card to convert incoming stream into a writable word for PC. The technique for designing a PC interface card is well-known and not very complicated. As there are built-in I/O routines for a PC, the development of (dedicated) software can be done without great difficulties. When the hard disk of a PC are fully used with the archived image data, an (low cost) external memory device such as an exabyte tape driver is used to store image data. The next section will describe the development of this PC interface card in detail.

After the incoming data are recorded in a hard disk of a PC, they need further processing. They contain not only image data but also auxiliary data and frame header/footer. A proper image data and auxiliary data need to be extracted and restored in a pre-defined format. This process is called a frame synchronization procedure. In some ground receiving stations for commercial remote sensing satellites, this procedure is done by a dedicated hardware. However, as emphasized earlier, the speed of the KITSAT-3 eliminates the need of a dedicated hardware. Frame synchronization can be done by software.

The use of dedicated software for frame synchronization reduces the cost of the total receiving station. This approach also has many other advantages compared to the conventional systems: the system can be easily maintained and error-handling is simple; the system can be easily modified to handle image data from other satellite as the frame synchronization is done through software; the system upgrade can be easily done with the fast development of computer hardware technologies. In the next section, the development of this frame synchronization software will be described.

After frame synchronization, image data are stored in a hard disk of a PC. This image data is "raw" image of the KITSAT-3. Further preprocessing, such as radiometric correction and/or geometric correction, can be performed as requested (see Lee et al.). The raw image data are displayed using a Moving Window Display so that operator can validate the quality of incoming image data.

After frame synchronization, image data is properly recovered and stored into the hard disk of a PC. To these image data , further processes such as geometric or radiometric correction can be applied. In figure 1, high speed recording, frame synchronization, and moving window display processes are performed at the same time as the antenna receives the signal from the satellite (on-line). External archiving is performed when the microprocessor of a PC is idle (off-line).

3. The development and Implementation of the KITSAT-3 Direct Archiving and Preprocessing System

3.1. The direct archiving recorder - development of a PC interface card

As explained earlier, the problem of developing a recorder using PC can be simplified as designing a PC interface card and developing a software to control I/O operation of a PC. The development of software is simple as there are many built-in I/O routines. This subsection will concentrate the development of a PC interface card.

The followings are the definition of the input and output of the PC interface card.

Table 2. The definition of input and output for the PC interface card

Input A: Two serial input (I, Q channels) with a speed of 3 Mbps.
Input B: One serial input(I, Q combined)
Clock A : A clock signal synchronous to the I, Q channel input
Clock B : A clock signal synchronous to the I, Q combined input
Output A : A word of 16 bits (After combining I and Q channels to a meaningful word)
Output B : A word of 8 bits

The input signal is created from the KITSAT-3 receiver (i.e., the down converter and bit synchronizer of the KITSAT-3 receiving station) as shown in figure 1. It is assumed that there are two possibilities of input signal. One possibility is to have two serial input streams with the speed of 3 Mbps. As the KITSAT-3 uses Quadratic Phase Shift Keying (QPSK) scheme, the output signal from the receiver can be two serial input of I and Q channels. The other possibility is to have one serial input stream. In this case, the KITSAT-3 receiver combines I and Q channels internally. When the input to the interface card is two serial streams, the output from the interface card is a 16-bit parallel word. A "read" command stores a 16-bit word into the hard disk of a PC. When input is one serial stream, the output is a 8-bit parallel word.

The incoming clock signal is assumed to be synchronous to the input streams. However, in order to ensure the operation of the interface card when the KITSAT-3 receiver cannot provide accurate clock signal, an internal clock generator is also included. A block diagram for the PC interface card is shown in figure 2.

Let's consider one input stream first. As the KITSAT-3 uses a scrambling algorithm for transmission, the input stream needs to be de-scrambled. The de-scrambling algorithm is dependent on the scrambling algorithm used onboard. After de-scrambling, the serial stream is converted into a parallel word using a First-In-First-Out memory device. For this, a FIFO IC device is used. One of the most suitable devices for this purpose is the IDT72103 FIFO memory chip. This can handle fast input signals and convert them into parallel words with varying bit-width. This can store the parallel words of upto 4Kbytes in its internal memories. This also provides various flags indicating the status of its internal memories.

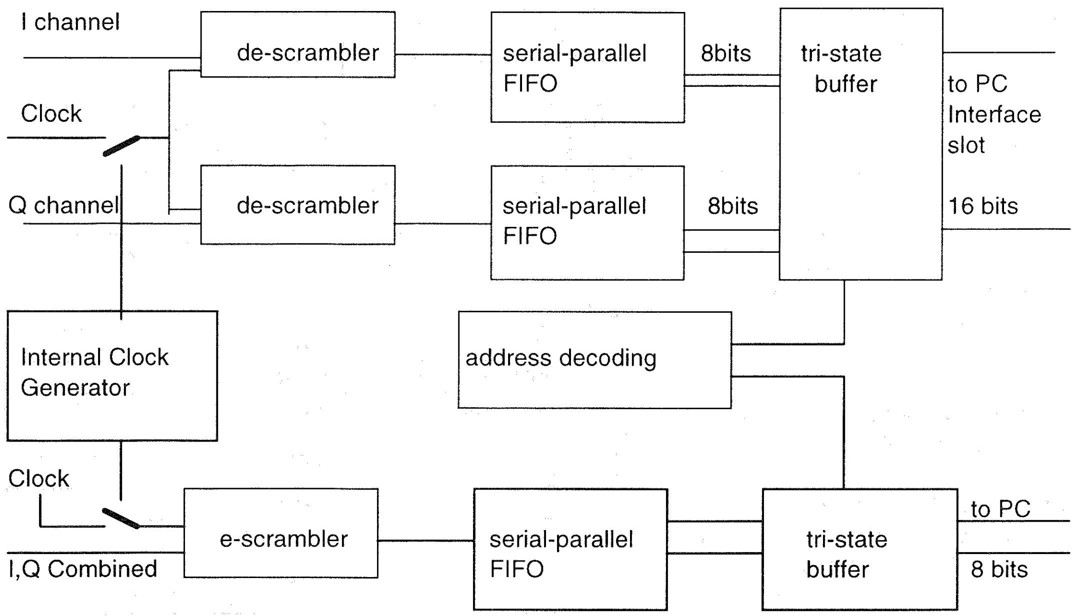

Figure 2. A Block Diagram of the PC Interface Card

After the input stream is converted into a parallel word and stored in the internal memory of a FIFO device, this parallel word needs to be read by a PC. This procedure can be done using built-in I/O routines. Using such routines, a microprocessor of a PC will check and read its I/O port specified by address. In order to assign an appropriate address to the FIFO memories of the PC interface card, an address decoding circuit should be designed. In this paper, a simple address decoding circuit was used (Chun, 1992) using a 74138 decoder. The selected address for the interface card is as follows.

Table 3. Selected addresses for the interface card

address	Meaning
330H	16 bits data input
332H	8 bits data input
333H	8 bits flag input
334H	16 bits flag input

As shown above and in figure 2, there are two paths of input stream. One path has two input streams and 16-bit output words. The other path has one input stream and 8-bit output words. In case of 16-bit output, two FIFO devices are used for serial-to-parallel conversion and output from each FIFO are combined to create 16-bit parallel word. In case of 8-bit output, I and Q channels are assumed to be combined within the KITSAT-3 receiver.

The basic I/O routines of a PC are done using 8-bit word. In order to control I/O port of a PC in 16 bits, the "-IO CS 16" pin of a PC's interface slot should be controlled carefully (Eggebrecht, 1992).

Table 3 shows that two addresses are allocated to read flags of FIFOs. Flags indicate the status of the internal memory of a FIFO. By reading these, it is possible to know whether the FIFO's memory is full, empty, half, etc.. In the software to derive the PC interface card, these two addresses are read continuously. When half of FIFO's internal memories are full, the microprocessor will read out parallel words stored in the memory.

Figure 2 shows that there is an internal clock generator in the PC interface card. This is to prepare the situation where the KITSAT-3 receiver fails to provide an accurate clock signal. The switch between internal and external clock can be implemented using software but a physical switch is used for the current implementation.

After the incoming bit stream passes the PC interface card, they are converted into parallel words and stored in the hard disk of a PC. Then, they undergo the frame synchronization process. The next subsection will describe the frame synchronization software.

3.2 Frame synchronization

The data stored into the hard disk of a PC contains not only image data but also auxiliary data such as telemetry data and header/footer. Moreover, the data stored in the hard disk may contain some dummy signals before frame header and/or after frame footer. Therefore it is important to identify the location of frame header and extract the meaningful content from a frame. This procedure is called Frame synchronization.

The implementation of frame synchronization software is straight forward as long as the structure of a frame is determined. Therefore this subsection will concentrate the structure of frames of the KITSAT-3 image data.

There are two transmission mode for the KITSAT-3. The *full transmission mode* is to transmit the image data stored in the solid-state mass memories into the ground station. The transmission is done in a full scale (no reduction). The *sub-sampled transmission mode* is to transmit sub-sampled image data (by the factor of 5) into the ground station. This mode is used to monitor in real-time the quality of images which the onboard camera takes.

In the sub-sampled transmission mode, a data frame is defined as table 4. A sub-sampled data frame starts with a synchronization word of 4 bytes. Frame synchronization software uses this word to define the starting point of a data frame out of the incoming bit stream. Scene number is to distinguish image data when the image data transmission is performed over multiple scenes (The KITSAT-3 can take upto 20 scenes at one time). Frame type is to distinguish whether a data frame is for the sub-sampled image data frame or other types. A sub-sampled data frame has the total size of 4327 bytes.

Table 4. Sub-sampled image data frame.

Data type	Size
Synchronization word	4 bytes
Scene No. and frame type	6 bits + 2 bits, i.e. 1 Byte
Frame No.	2 Bytes
Sub-sampled image data	4320 Bytes
Total	4327 Bytes (34616 bits)

In the full transmission mode, there are two types of data frame. One is a full image data frame and the other is a telemetry data frame. The structure of each frame is shown in table 5 and 6.

The total size of a full image data frame or a telemetry data frame is same as that of a sub-sampled image data frame. However, in a full image data frame, the size of image data is 3456 bytes, which corresponds to the amount of data collected from one line of the KITSAT-3 CCD array. Unlike a sub-sampled image data frame, a full image data frame and telemetry data frame contain an error detection code for more accurate transmission. In a full image data frame, 2 bits are assigned to indicate the spectral band of an image (RGB). Frame number is used to distinguish each full image data frame. As a KITSAT-3 image scene is defined as 3456 pixels by 3456 pixels, 3456 image data frames are combined to create a scene in a single spectral band.

Table 5. A full image data frame

data type	Size
Synchronization word	4 bytes
Scene no. and frame type	6 bits + 2 bits, i.e., 1 byte
RGB and Frame No.	2 bits + 12 bits, i.e., 2 bytes
Image data	3456 bytes
Error Detection code (1:4)	864 bytes
Total	4327 bytes (34616 bits)

Table 6. A telemetry data frame

data type	size
Synchronization word	4 bytes
Scene No. and frame Type	6 bits + 2 bits, i.e., 1 byte
Frame No.	2 bytes
Telemetry Data	3456 bytes
Error Detection code (1:4)	864 bytes
Total	4327 bytes (34616 bits)

Commercial remote sensing satellites normally have a frame structure which has image data and telemetry data in the same frame. However, telemetry data of the KITSAT-3 is transmitted separately as a telemetry data frame. This is due to hardware limitations of the KITSAT-3 onboard imaging instrument. The telemetry data sampling rate of the KITSAT-3 is not high (5~10 Hz) and the amount of telemetry data for a scene is very small. One telemetry data frame is enough to cover whole telemetry data for an image scene.

After the data from the PC interface card are converted into a appropriate format, they are restored into the hard disk of a PC. The proper image data are then used for further processing such as geometric or radiometric correction.

4. Conclusions

So far, this paper briefly described the development of a low cost direct archiving system and a frame synchronization software. The developed system will be used for the archiving and preprocessing of the KITSAT-3.

The motivation of this development was to design a low cost ground receiving station for small satellites. The use of dedicated hardware was therefore abandoned and dedicated software with commercial PC was used instead.

The techniques used for this development are not very complicated and some of them are even very simple. This shows the advantage of using small satellites in the sense that the ground receiving station can be developed easily.

Compared to other commercial satellites, the transmission speed for the image data from this satellite is low. This may have made it easier to develop the low cost direct archiving and preprocessing system. However, at least some part, if not all, of the system developed here can be applicable for preprocessing of the image data from commercial remote sensing satellites and can be used to reduce the cost of archiving and preprocessing system for such satellites. Moreover, given the fast development of computer hardware, the speed limit of the low cost archiving and preprocessing system developed here should reach to the data rate from commercial satellites in near future.

References

[Chun, 1992] YoonSoo Chun, "Design of a general PC Interface Card", Microsoftware, pp. 376-382, June 1992 (Written in Korean)

[Eggebrecht, 1992] Lewis C. Eggebrecht, "Interfacing to the IBM Personal Computer", 2nd Edition, published by SAMS, 1992

[Kim et al., 1995] Sungheon Kim et al., "Mission Overview of Engineering Test Satellite, KITSAT-3", Proc. Of the 9th Annual AIAA/USU conference on Small Satellite, Sep. 18-21, 1995, Utah State Univ., Utah, USA

[Kim et al., 1995] "Three-axis Reaction Wheel Attitude Control System for KITSAT-3 Microsatellite", Proc. Of International Conference on Intelligent Autonomous Control in Aerospace '95, pp. 537-542, Beijing, P.R. China. August 14-16, 1995